NORTH SEA REGION ELECTRIC MOBILITY NETWORK

e-mobility NSR

Technical Report on EV Laboratory Tests

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Executive summary

This report refers to the laboratory tests conducted in the work-package “Smart Grid Solution”, with the scope of measuring EVs storage capacities, as well as their charging needs and their energy consumption, of EVs currently on the market and simulating their daily utilization.

Laboratory tests on EVs have been committed by Transenergy (TEF), and then by Ghent University to the Thomas More laboratories and were operated during the three years of the project.

The methodology was based on two different data sources:

- Manufacturers’ type-approval values, measured under laboratory conditions with certain flexibilities and making use of a standardized test cycle, the NEDC.
- Tests conducted in the Lessius Labs, under conditions that are supposedly more realistic, making use of the NEDC as well as calculating the air and roll resistance coefficients through two Freewheel Cycle.

In the first year, it was established a reference framework for an independent comparison of the different EVs. As first try-out car, it was used a Think! City. During the second year, tests continued on Mitsubishi i-Miev, Renault Kangoo ZE, and partially repeated on the Think! City. During the final year, also Nissan Leaf was included in the tests.

Tests were of two types, freewheel and lab tests, on a roller bench MaHa 3000. The firsts were necessary for fully identifying significant vehicle parameters in terms of air and roll resistance. Therefore, an entire chapter has been devoted to those tests.

Those tests demonstrated that roll resistance coefficients for EV are very similar, with differences of less than 10%, being the cars all equipped with ECO tyres. In terms of air resistance, only the Renault Kangoo ZE, having a large front surface, has the highest score.

The power test bench has been driven under the option “drive simulation’, in order to determine the EVs energy consumption according the NEDC cycle. The test also supports the measurement of the usage per km, obtained by dividing the used energy by 11.06 km, that is, the length of the NEDC cycle.

Results show that, in terms of energy consumption, Think!City scores very close (211 Wh/km) to the manufacturer specified value (190 Wh/km). Mitsubishi i-Miev scores (167 Wh/km) better than the Think!City, mainly because both roll and air resistance power are lower. It is also equipped with a PM synchronous engine, which achieves a better yield than the a-synchronous engine of the Think. Consumption values for the Renault Kangoo ZE are high (216 Wh/km), which is normal because it has the highest power. Nonetheless, that is in opposition with the manufacturer specified consumption, which does not appear to be realistic (129 Wh/km).

About Nissan Leaf tests, they take into account that is the heaviest vehicle and, therefore, with the highest roll resistance. However, the high mass represent a relevant potential for energy recuperation, which on the contrary was not taken into account in the tests. In addition, differences between version I and II, as well as some Maha testing bench settings problems, did not provide a fully satisfying result, with a value of 200 WH/km, which is significantly higher than the 140 Wh/km that was specified. After the tests, it became evident that a consumption of 200 Wh/km on a NEDC cycle can be considered normal.

As far as electric consumption is concerned, the numbers largely confirm the understanding that a large, heavy vehicle consumes more than a small, lightweight vehicle. Which technology is used also plays a role; the PM synchronous engine transmission showed the best results.

The numbers for transmission yields also provide an evident statement; the steady loss of the motor controllers has a negative effect if the transmission load is low. There is no way to determine the yield on an electric vehicle given the fact that it varies enormously depending on its load.

Another loss of approximately 20% occurs during charging, because of which the total yield decreases. In order to obtain the total yield, the average transmission yield must be multiplied by the charging yield.

Finally, The various vehicles all display the readable parameters differently. It will be a huge challenge to identify/calculate the correct results from the future logging process.

Glossary

Anti-lock Braking System (ABS): is an automobile safety system that allows the wheels on a motor vehicle to maintain tractive contact with the road surface according to driver inputs while braking, preventing the wheels from locking up (ceasing rotation) and avoiding uncontrolled skidding.

Battery management system (BMS): is any electronic system that manages a rechargeable battery (cell or battery pack), such as by monitoring its state, calculating secondary data, reporting that data, protecting the battery, controlling its environment, and / or balancing it. The BMS also controls the recharging of the battery by redirecting the recovered energy (i.e. from regenerative braking) back into the battery packs (a pack is typically composed of a few cells).

CAN-Bus (Controller area network): is a vehicle bus standard, designed to allow microcontrollers and devices to communicate with each other within a vehicle without a host computer.

Data Logging: is the process of recording events, with an automated computer program, in a certain scope in order to provide an audit trail that can be used to understand the activity of the system and to diagnose problems. For EVs is necessary to collect information about travel performance, consumption, driving behaviours, and energy absorption.

Electric Vehicle (EV): uses one or more electric motors or traction motors for propulsion. Three main types of electric vehicles exist: directly powered from an external power station (Tram, trolley bus); powered by stored electricity originally from an external power source (Battery Electric Vehicle, BEV); powered by an on-board electrical generator, such as an internal combustion engine (Hybrid Electric Vehicle, HEV) or a hydrogen fuel cell.

MFP 3000 by MAHA: is a test bench allowing a test drive and performance testing of safety systems and driving assistance systems on a vehicle lift.

New European Driving Cycle (NEDC): is a driving cycle, designed to assess the emission levels of car engines and fuel economy in passenger cars (excluding light trucks and commercial vehicles). The first part of the driving cycle (Phase 1) represents urban driving, in which a vehicle is started in the morning (after being parked all night) and then driven in stop-and-go mode. The second part (Phase 2) represents extra-urban driving at a maximum speed of 120kph. The NEDC takes some 20 minutes and respectively covers distances of approx. 4km in Phase 1 (urban) and approx. 7km in Phase 2 (extra-urban).

Renewable energy (RE): is energy, which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable (naturally replenished). Renewable energy replaces conventional fuels in four distinct areas: electricity generation, hot water/space heating, motor fuels, and rural (off-grid) energy services

Smart Grid: is an electrical grid that uses computers and other technology to gather and act on information, such as information about the behaviours of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity.

Sustainability: is the capacity to endure. For humans, sustainability is the long-term maintenance of responsibility, which has environmental, economic, and social dimensions, and encompasses the concept of stewardship, the responsible management of resource use. Sustainability interfaces with economics through the voluntary trade consequences of economic activity. Moving towards sustainability is also a social challenge that entails, among other factors, international and national law, urban planning and transport, local and individual lifestyles and ethical consumerism. Ways of living more sustainably can take many forms from controlling living conditions (e.g., ecovillages, eco-municipalities and sustainable cities), to reappraising work practices (e.g., using permaculture, green building, sustainable agriculture), or developing new technologies that reduce the consumption of resources.

1. Introduction

The work-package "Smart Grid Solution" aims at developing models of Smart Grid able to support a sustainable use of the electric mobility in the NSR region. Objective of a **smart electric grid** is to integrate the actions of all connected actors, producers and consumers, for distributing energy in efficient, sustainable, reliable and safe mode. Relevant elements for developing a smart grid approach in the field of the electric mobility are:

- Renewable energy production (solar, wind, co-generation, …)
- EVs electricity consumption (vehicle performance, batteries, battery management systems (BMS), transportation service, users behaviours, etc)
- Charging stations (slow & fast charging modes), metering, V2G-applications and other grid connections

Although the renewable energy production is not a topic for this project, its efficient use and integration in the grid could be facilitate by its interaction with the EVs. Their batteries could provide additional capability for integrating energy from renewable sources and achieving sustainability from well to wheel. However, a lot of information are missing from both the energy and the transport sides.

Goals of lab tests was measuring EVs storage capacities, as well as their charging needs and their energy consumption. Tests took only into account EVs currently on the market and simulating their daily utilization. In fact, considering the market growth and the evolving awareness of the users, a laboratory test or a short running field simulation could fail to provide robust results if not related to the EVs market development during its project life.

Laboratory tests on EVs have been committed by Transenergy (TEF), and then by Ghent University to the Thomas More laboratories and were operated during the three years of the project.

Main scope of this report is to define a coherent lab tests methodology for EVs and then to describe tests conducted in the Lessius labs and results.

The methodology is based on two different data sources:

- Manufacturers' type-approval values, measured under laboratory conditions and making use of the NEDC, a standardized test cycle.
- Tests conducted in the Lessius Labs, under conditions that are supposedly more realistic, also making use of the NEDC.

In the first year, a reference framework was established for independently comparing different EVs. To that scope, a Think! City was used as the first try-out car. During the second year, tests with the roller bench MaHa 3000 have been ran on the Mitsubishi i-Miev, the Renault Kangoo ZE, and partially repeated on the Think! City. During the final year, also the Nissan Leaf was tested.

In the reference framework it has been decided to preliminarily perform freewheel tests and to identify the most significant vehicle parameters. Therefore, an entire chapter has been devoted to those tests. Freewheel tests have been fully completed on the Mitsubishi I-Miev, the Renault Kangoo ZE and the Nissan Leaf. On the contrary, for the Think! City the freewheel tests have been only partially performed. Based bench tests conducted at the Campus De Nayer, the EVs values could be finally compared with the manufacturers' ones. To obtain information about the vehicle (e.g. current, voltage, battery capacity, distance, charging conditions, and how the network topology of the vehicle is composed), a CAN-Bus analyser was used. Transferring the binary code to usable values has been the final and most difficult step.

Fig. 1: The Try-out of the Think!City

2. Manufacturers' type-approval values

2.1 The New European Driving Cycle (NEDC) testing protocol

Before being allowed to sell a new vehicle model on the market, a manufacturer needs to follow the so-called Type-Approval (TA) process. As part of this process the manufacturer determines the emission of carbon dioxide and fuel consumption for conventionally fuelled vehicles and/or the electric energy consumption and electric range for the pure electric vehicles, simulating the road load of the vehicle with the help of input factors that have been measured earlier on a road track. All tests follow procedures that are regulated in European Union and UNECE (United Nations Economic Commission for Europe) legal documents. A central document is the Regulation (EC) No. 715/2007. The method of measurement is based on a test sequence composed of two parts: (a) an urban cycle made of four elementary urban cycles; (b) an extra-urban cycle.

The type approval test will normally take place at the premises of the manufacturer, under the authority of the technical service of the respective EU member state. If the prescribed procedures have been followed, required tolerances are met and limits are not exceeded, type-approval will be granted by the national type approval authority.

Applying a standardized test procedure that is the same for all vehicles in all EU member states (and beyond) has the advantage of repeatability and comparability of results. The driving cycle that is used to simulate the driving pattern of the tested vehicles, the New European Driving Cycle (NEDC) according to directive 98/69/EC, is always the same and therefore ensures that the CO_2 value of one vehicle is directly comparable to another vehicle. The NEDC is shown in Figure 2. The first part represents urban driving, in which a vehicle is started in the morning (after being parked all night - only in cold test) and driven in stop-and-go rush hour traffic. The second part represents extra-urban driving with a maximum speed of 120 km/h.

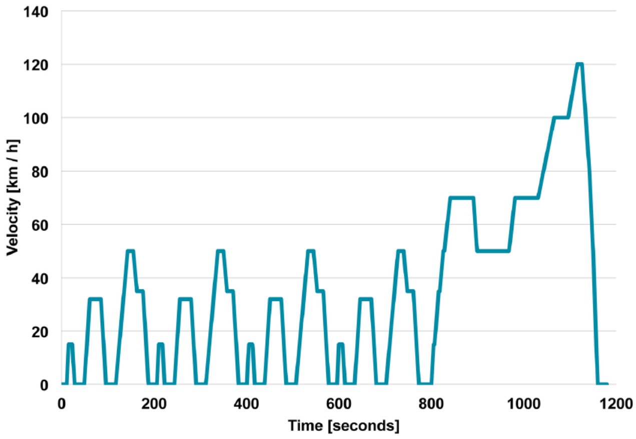


Fig. 2: Speed profile of New European Driving Cycle (NEDC)

2.2 Think!City

Engine type:	3-phased asynchronous induction engine (Leroy-Somer)
Engine power:	34kW peak/ 25kW continuous
Battery:	Li-Ion
Recharging time:	8 h
Energy storage:	23 kWh
Battery weight:	260 Kg
Maximum speed:	112 Km/h
Acceleration:	0-80 Km/h in 16 sec
Autonomy:	160 Km (according to NEDC cycle)
Vehicle mass:	1190 kg
Electric energy consumption:	144 Wh/km (according to NEDC cycle)

Fig. 2: Think!City

2.3 Mitsubishi i-Miev

Engine type:	Synchronous engine/ 3-phased permanent magnet
Engine power:	47kW
Battery:	Li-Ion
Recharging time:	6 h (230V/16A)
Energy storage:	16 kWh
Battery weight:	-
Maximum speed:	130 Km/h
Acceleration:	-
Autonomy:	160 Km (according to Japanese 10-15 test modus)
Vehicle mass:	1120 kg
Electric energy consumption:	-

Fig. 3: Mitsubishi i-Miev

2.4 Renault Kangoo ZE

Engine type:	Synchronous engine/ 3-phased permanent magnet
Engine power:	44kW
Battery:	Li-Ion
Recharging time:	6 to 9 h (230V/16A)
Energy storage:	22 kWh
Battery weight:	-
Maximum speed:	130 Km/h
Acceleration:	-
Autonomy:	170 Km (according to NEDC cycle)
Vehicle mass:	1410 kg
Electric energy consumption:	129 Wh/km (according to NEDC cycle)

Fig. 4: Renault Kangoo ZE

2.5 Nissan Leaf

Engine type:	synchronous engine/ 3-phased permanent magnet
Engine power:	80kW
Battery:	Li-Ion
Recharging time:	8 h (230V/16A)
Energy storage:	24 kWh
Battery weight:	-
Maximum speed:	-
Acceleration:	-
Autonomy:	170 Km (according to NEDC cycle)
Vehicle mass:	1512 kg
Electric energy consumption:	140 Wh/km (according to NEDC cycle)

Fig. 5: Nissan Leaf

3. Consumption tests (NEDC cycle)

Many studies pointed out that the current NEDC is not representative of real-life driving conditions but is rather a stylized driving speed pattern with low accelerations, constant speed cruises, and many idling events. Therefore, our lab tests on EVs use the NEDC only after having defined restistance parameters with the freewheel test described in the next paragraph.

3.1 Freewheel test and deduction of vehicle parameters

Freewheel test goal is determining the vehicle's different resistances, such as air and roll resistance. Both types of losses are getting increased attention because of new mandated improvements in fuel economy and because of the constraints of electric cars, which are fuel-limited since batteries are so heavy. Electric cars have a high premium on keeping losses low to extend their range between charges.

Subsequently, the resulting parameters are applied to the power brake in order to run the NEDC cycle. To this end, each vehicle must undergo two separate freewheel tests, at different average speed, in order to calculate air and roll resistance and measure both speed reductions.

In general, roll resistance is calculated as follows:

$\mathbf{F_{Roll} = C_r \times m \times g}$

With:

C_r = rolling coefficients for pneumatic tyres (0.015 for ordinary car tires on concrete, 0.03 for car tires on tar or asphalt)
m = the vehicle's mass, including passengers
g = the earth's gravitational acceleration (9.81 m/sec^2).

Therefore, roll resistance does not depend on speed but by the vehicle mass and road surface. On the contrary, speed is relevant for the air resistance, which is calculated as follow:

$\mathbf{F_{Air} = A/2 \times C_d \times D \times v^2}$

With:

A = frontal area of the car in m^2
C_d = drag coefficient (for cars, between 0.25 and 0.50)
D = density of air (1.29 kg/m^3)
v = speed in m/sec.

For running a freewheel test, the wheel rotation speed must be determined by using an **Anti-lock Braking System (ABS) sensor,** normally employed to prevent lock up when braking. However, active ABS sensor signal is current-controlled and its measurement not always easy. The first paragraph will describe the chosen solution for the ABS signals.

3.2.1 The ABS sensor

As regularly used in the ABS steering box to determine the wheel speed, the chosen solution was a differential amplifier (Figure 7). The signal transmission to the ABS steering box takes place in the form of a current signal in an impulse-wide modulation procedure (Source: http://www.hella.com/hella-be/index.html?rdeLocale=nl).

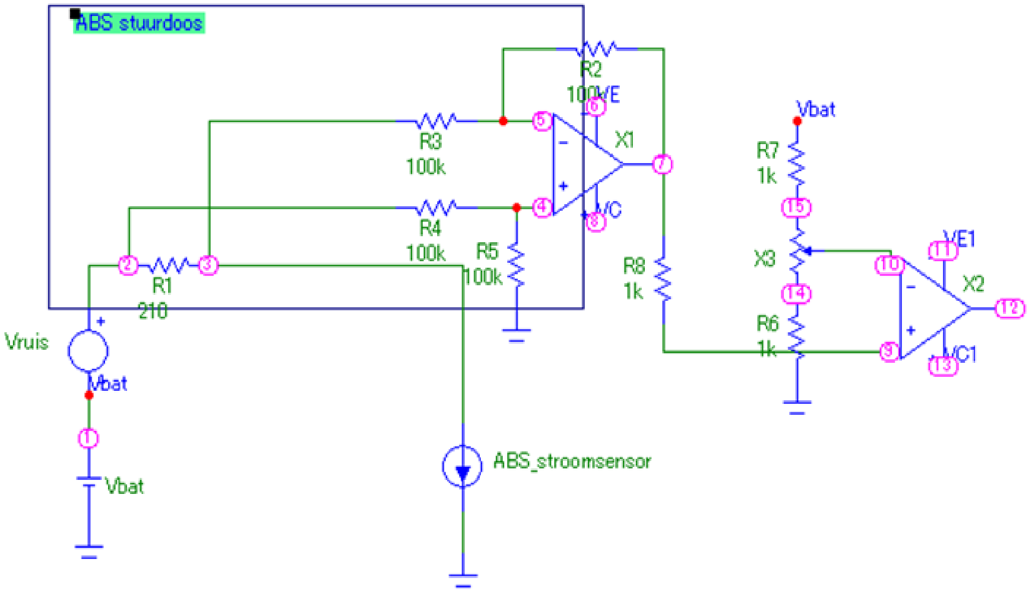


Fig. 7: Signal transmission to the ABS steering box

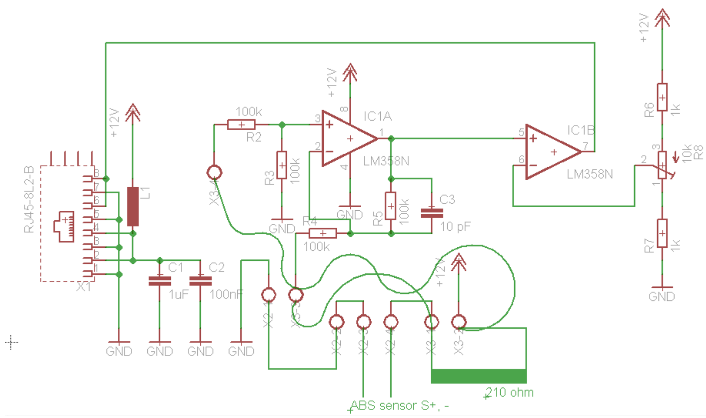
The largest difference in voltage occurs at a differential resistance of R1 of 210 Ω (Table 1), which is the resistance used by all tested EVs, with the exception of the Nissan Leaf (resistance of 100 Ω). Therefore, EVs have a resistance of 210 Ω, with a current difference of 4.0 mA (**ΔI**), when the North and South poles are exchanged and the voltage changes with a maximum value of 0.85 V. A 6V battery via R1 has separately supplied the ABS sensor.

R1	Umax	Umin	ΔU	(6V-Umax)/R	(6V-Umin)/R	ΔI
(Ω)	(V)	(V)	(V)	(mA)	(mA)	(mA)
33	5,82	5,6	0,22	5,5	12,1	6,7
100	5,34	4,93	0,41	6,6	10,7	4,1
210	4,99	4,14	0,85	4,8	8,9	4,0
470	4,06	3,26	0,8	4,1	5,8	1,7
1000	3,08	2,86	0,22	2,9	3,1	0,2

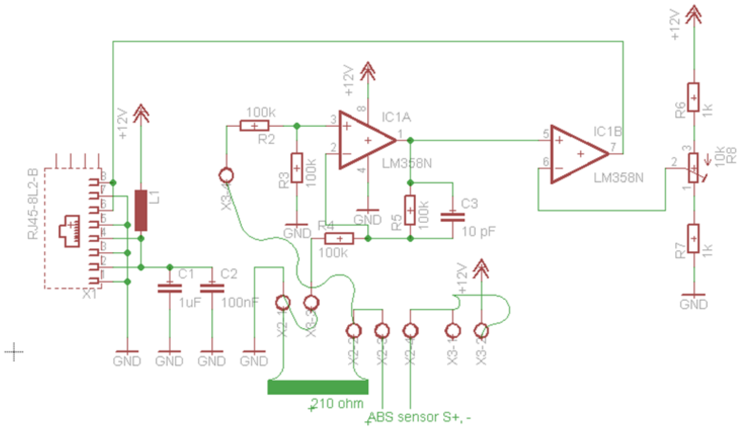
Tab. 1: Differences in voltage

There are two possible setups:

1. Sensor with signal in supply line, to be turned on as displayed below (Figure 8):



2. Sensor with signal on minus side, to be turned on as displayed below (Figure 9):



That leads to the following conversion board:

Sizes 2.2 inch on 1.65 inch = 56 on 42 mm

This conversion allows for an extremely undistorted square wave for the deceleration meter. Please note that that the ABS sensor is disconnected during the freewheel tests and connected to the conversion circuit in Figure 10. Therefore, the ABS is switched off during the freewheel tests.

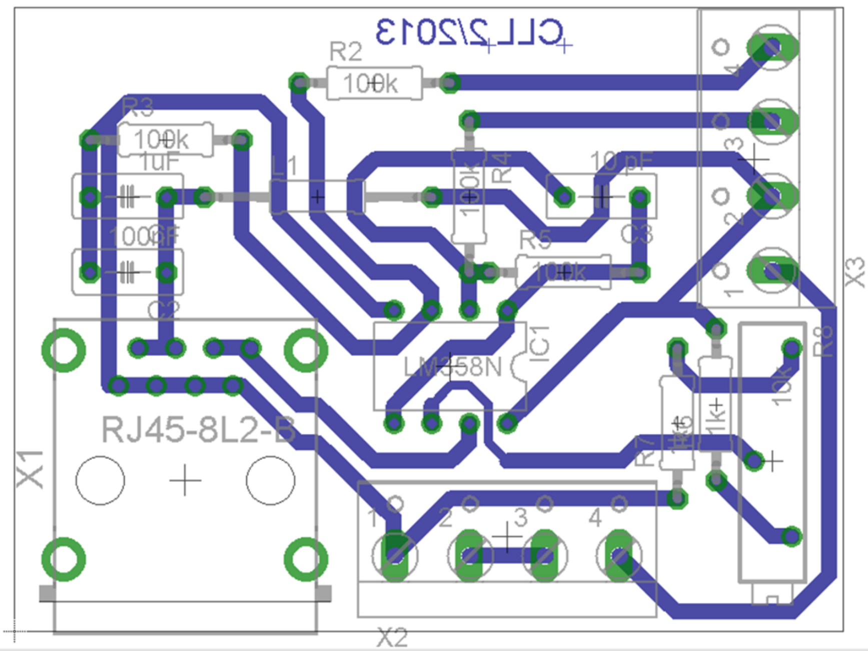


Figure 10: The conversion circuit

3.2.2. The deceleration meter

The deceleration meter is a micro controller that determines the vehicle deceleration by using two timers. The entry signal of the above discussed conversion circuit provides an undistorted square wave. The rising edge of the entry signal creates an interruption for the first timer, which is checked to see whether the period of the entry signal complies with the vehicle's entry speed. If so, a second timer is turned on and continues to run until the period of the entry signal complies with the end speed. Other complex control algorithms were added. The inputs are the number of pulses per wheel diameter, entered through a software interface, and the distance (in mm) travelled by the vehicle during one wheel revolution. The programme consistently provides the stop time during the freewheel test in a txt-file. Multiple tests can be conducted one after the other and all will be included in the same txt-file. The configuration of a vehicle can also be stored in the programme for a later re-use.

3.2.3. Freewheel tests

Two types of freewheel tests have been conducted on each EV: a first test from 55 kph to 50 kph and a second one from 25 kph to 20 kph. During the low speed freewheel tests the air resistance is less relevant than during the fast freewheel test because speed is squared in the above-mentioned equation, as well as the roll resistance become more and more insignificant the faster the car will be, not changing with the speed of the vehicle

The outdoor temperature was measured during each test and varied between 6° C and 20° C. Tyre pressure was controlled and set up at the manufacturer suggested value.

The vehicles freewheeled on a plain road in both driving directions, in order to eliminate the effect of the wind and any potential inclination. Tests were repeated until the statistical accuracy (p) was less than 4%. That mostly required nine measurements in both directions. The calculation of P was executed as follow (according to the E/ECE/324, more specifically E/ECE/Trans/505 Regulation No. 101 Annex 7 – Appendix):

P = $(F_{Roll} + F_{Air}) \times v$

At an average high velocity v_1 (52.5 kph) and an average low velocity v_2 (22.5 kph), the average decelerations a_1 and a_2 were determined as follow:

Test 1 (high velocity):	Test 2 (low velocity):
$m.a_1 = f_{rol}.m.g + \frac{1}{2}.\rho_l.A.C_x.v_1^2$ (1)	$m.a_2 = f_{rol}.m.g + \frac{1}{2}.\rho_l.A.C_x.v_2^2$ (2)

The following mathematical model (1) – (2) leads to:

$$m(a_2 - a_1) = \frac{1}{2}\rho_l.A.C_x(v_2^2 - v_1^2)$$

With the following result:

$$\Rightarrow C_x = \frac{2.m(a_2 - a_1)}{\rho_l.A(v_2^2 - v_1^2)}$$

Applying the air resistance coefficient (C_x) we can subsequently determine the roll resistance coefficient (f_{rol}).

$$m.a_1 = f_{rol}.m.g + \frac{1}{2}\rho_l.A.C_x.v_1^2$$

$$= f_{rol}.m.g + \frac{1}{2}\rho_l.A\frac{2.m(a_2 - a_1)}{\rho_l.A(v_2^2 - v_1^2)}.v_1^2$$

$$= f_{rol}.m.g.\frac{m(a_2 - a_1)}{(v_2^2 - v_1^2)}.v_1^2$$

$$\Rightarrow g.f_{rol} = a_1 - \frac{(a_2 - a_1)}{(v_2{}^2 - v_1{}^2)}.v_1{}^2 = \frac{v_2^2 a_1 - v_1^2 a_1 - a_2 v_1^2 + a_1 v_1^2}{(v_2^2 - v_1^2)}$$

$$\Rightarrow f_{rol} = \frac{v_2^2 a_1 - a_2 v_1^2}{g.(v_2^2 - v_1^2)}$$

With:

m = vehicle and passenger mass [kg]

a_1 = average deceleration at a high freewheel velocity [m/s²]

a_2 = average deceleration at a low freewheel velocity [m/s²]

ρ_l = air density 1,29 [kg/m³] if necessary corrected by measuring air temperature and air pressure

A = front surface [m²]

v_1 = high average freewheel velocity [m/s]

v_2 = low average freewheel velocity [m/s]

g = gravitation constant 9,81 [m/s²]

3.2.4. Results of vehicle parameters

The Table 2 shows an overview of the "Freewheel tests" completed for the tested EVs.

Vehicle	f_{rol} (-)	C_x (-)
Think City	0,015	0,39
Mitsubishi Imiev	0,013	0,33
Renault Kangoo ZE	0,014	0,31
Nissan Leaf II (with Michelin Eco tyre)	0,013	0,27
Nissan Leaf I (with Bridgestone Eco tyre)	0,015	0,31

Table 2: Roll and air resistance coefficients for the tested EVs

This demonstrates that roll resistance coefficients for EV are very similar, with differences of less than 10%. This makes sense, since the five cars were all equipped with ECO tyres.

The air resistance coefficient for the Renault Kangoo ZE is low, but then the calculation for air resistance power shows that the Kangoo ZE has the highest score, which makes sense since it has such a large front surface.

A Cx of 0.29 was specified for the Nissan Leaf II. The approach during our tests is reasonable; determining the front surface is still a weak point in our measuring method. To this end, we used the width (without mirrors) x height for all vehicles.

3.3 Test parameters on the roller bench MaHa 3000

The power test bench has been driven under the option “drive simulation’. When selecting this measurement on the power test bench the following screen will appear (Figure 11):

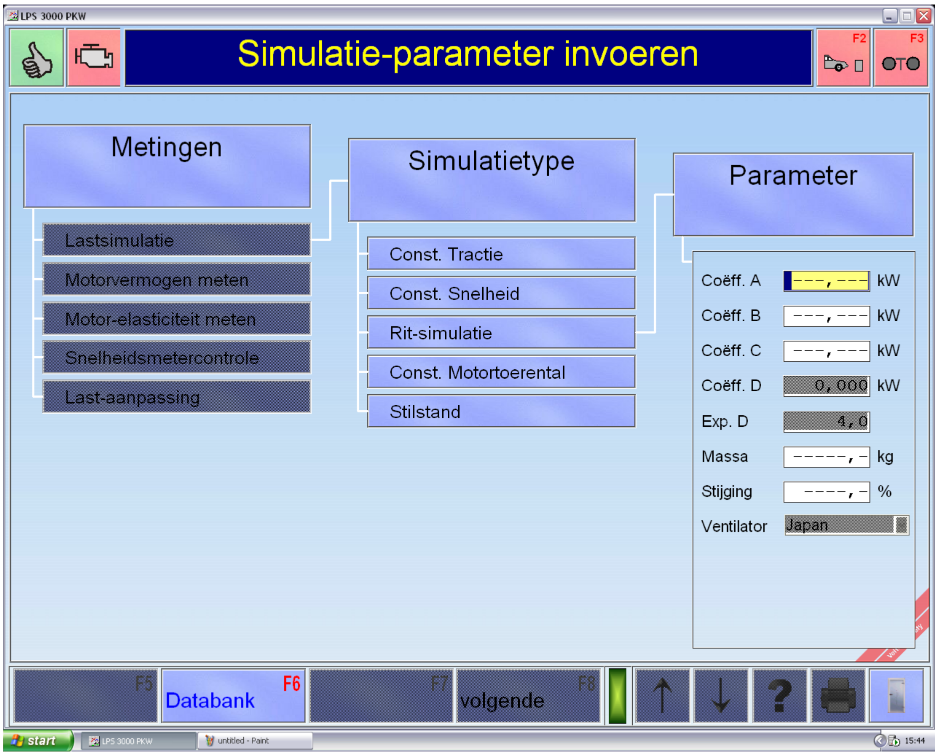


Figure 11: Entering simulation parameter

The test bench determines the deceleration power using these parameters. A correct value for the vehicle is therefore paramount for the NEDC consumption test.

- **Coefficient A [kW]:** loss of rolling power. This coefficient A is calculated with the following formula:

$$A = p_{rol} = f_{rol} m.g.v_{ref}$$

With:

- f_{rol} = roll resistance coefficient [-]
- m = Vehicle mass [kg]
- g = gravitation constant, drop acceleration, 9.81[m/s²]
- vref = reference velocity 90 [km/h] (25 m/s)

- **Coefficient B [kW]:** With this factor, value 1 takes the distortion of the tyres into consideration. However, this was already included in the previous coefficient. Normally, value 0 is introduced here.
- **Coefficient C [kW]:** air resistance power. It is calculate with the following formula:

$$C = P_{lucht} = \frac{1}{2}.\rho_l.C_x A_{front}.\left(v_{ref} + v_{wind}\right)^2.v_{ref}$$

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With:

- ρ_l = air density 1.29 [kg/m³] standard condition
- C_x = air resistance coefficient
- A_{front} = front surface of the vehicle [m²]
- v_{ref} = reference velocity, 25 [m/s]
- v_{wind} = wind velocity, 0 is entered here

The mass of the vehicle is entered and 0% is used for the gradient percentage for the NEDC. This leads to the values in Table 3:

Vehicle	**Coefficient A [kW]** (rolling power)	**Coefficient C [kW]** (air resistance power)
Think City	4,5	10,4
Mitsubishi i-Miev	3,9	8,2
Renault Kangoo ZE	5,1	8,8
Nissan Leaf II	5,1	6,8
Nissan Leaf I	5,9	8,5

Table 3

The Think! City's air resistance power is too high here, probably because freewheel test at high speed took place by using a chronometer rather than the speed log.

3.4 Consumption according to NEDC cycle

In this chapter, we are going to determine energy consumption according the NEDC cycle. In addition, dividing the used energy by 11.06 km - the length of the NEDC cycle – is possible to define the usage per km too. Tests results are reported in Table 4.

Vehicle	Measured consumption according to NEDC (Wh/km)	Specified consumption according to NEDC (Wh/km)
Think City	211	190
Mitsubishi I-miev	167	-
Renault Kangoo ZE	216	129
Nissan Leaf II	-	140
Nissan Leaf I	254	140

Table 4: Energy consumption according the NEDC cycle

Considering previous paragraph remarks, the Think! City should normally score better than 211 Wh/km. Its result is, therefore, very close to the manufacturer specified value (190 Wh/km). Mitsubishi I-miev scores better than the Think, mainly because both roll and air resistance power are lower. It is also equipped with a PM synchronous engine, which achieves a better yield than the a-synchronous engine of the Think. Consumption values for the Renault Kangoo ZE are high, which is normal because it has the highest resistance power.

Nonetheless, that is opposition with the manufacturer specified consumption, which does not appear to be realistic. About Nissan Leaf tests, they take into account that is the heaviest vehicle and therefore with the highest roll resistance. However, the high mass represent a relevant potential for energy recuperation, which on the contrary was not taken into account in the tests.

During the tests on the Nissan Leaf II, the settings on the Maha testing bench were set incorrectly. As a result, a new test on the Nissan Leaf needed to be conducted at a later date. This time it was an older version with a different type of tyres and it was a Leaf I. Given the higher roll resistance (which was no less than 15%) and the higher air resistance (25% at 90 kph) of the Leaf I, the Leaf II's consumption should be approx. 20% lower. This would result in a value of 200 WH/km, which of course is still significantly higher than the 140 Wh/km that was specified.

After the tests, it became evident that a consumption of 200 Wh/km on a NEDC cycle can be considered normal.

Very important remarks regarding the comparison are:

- The power bench does not have a propulsion engine. Therefore, the 11 deceleration phases in the NEDC cycle are not reliable. The consumption values with energy recuperation will decline with another 10 per cent and for the Nissan Leaf probably even more. Therefore, it is difficult to compare the five vehicles with each other. With partial energy recuperation (own mass rolls) the Mitsubishi i-Miev has the highest score.
- If additional electrical systems are turned on inside the vehicle, the use of electricity increases enormously. With the Think it even goes up to 400 Wh/km.

4. Total transmission yield

To determine the transmission yield, the power transferred to the wheels (Pw) is divided by the electric power (Pt) that is provided by the battery. To this end, the test bench Maha 3000 is set at ‘constant tractive power’. By applying the gas pedal until the required speed is reached, the vehicle must provide a certain amount of power as shown in below table. The maximum wheel power is 50 kW, which is too high for the Think!City, i-Miev and Kangoo Ze. For the Nissan Leaf this is approximately 60% of its maximum power.

	Pwheel (kW)			
traction (N)	**30 kph**	**50 kph**	**70 kph**	**90 kph**
100	0,8	1,4	1,9	2,5
250	2,1	3,5	4,9	6,3
500	4,2	6,9	9,7	12,5
1000	8,3	13,9	19,4	25,0
1500	12,5	20,8	29,2	37,5
2000	16,7	27,8	38,9	50,0

Table 5: Wheel power

This results in a yield chart per vehicle, as seen below for the Think! City (Figure 12).

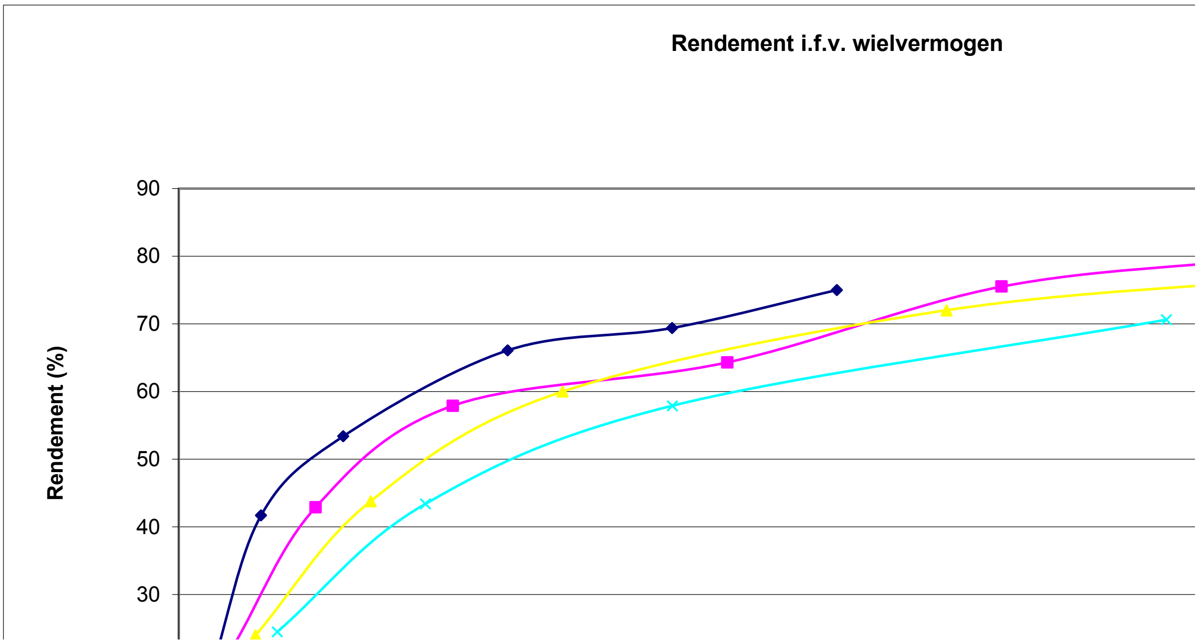

Figure 12: Yield Chart for Think!City

From the Figure 12, two tendencies are clear. First, the yield drops when power is low, because of permanent losses of convertor and engine. Second, the yield drops at higher speeds with the same power. That behaviour depends on the higher hysteresis loss in the engine. The comparison of yields among different EVs was realised at different speeds. The vertical axis shows the yield, the horizontal axis shows the traction in N.

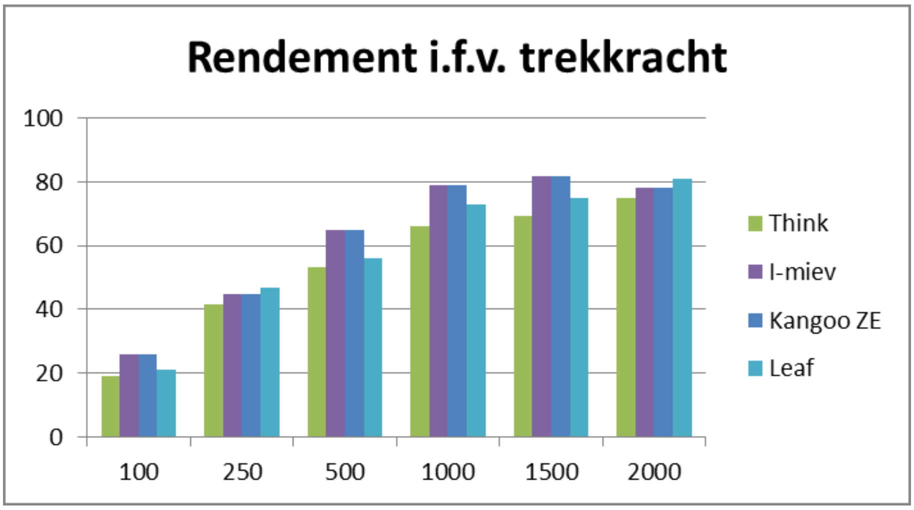

Figure 13: Comparison of yields at 30 kph

At 30 kph (Figure 13) the Kangoo ZE and the i-Miev both achieve the same yield. The Think’s yield is lower because of its a-synchronous engine. The Leaf follows the same line, although it slightly lags behind. This can be explained by its higher maximum power. For the Leaf engine, these loads are lower regime loads, which explains the slightly lower yield.

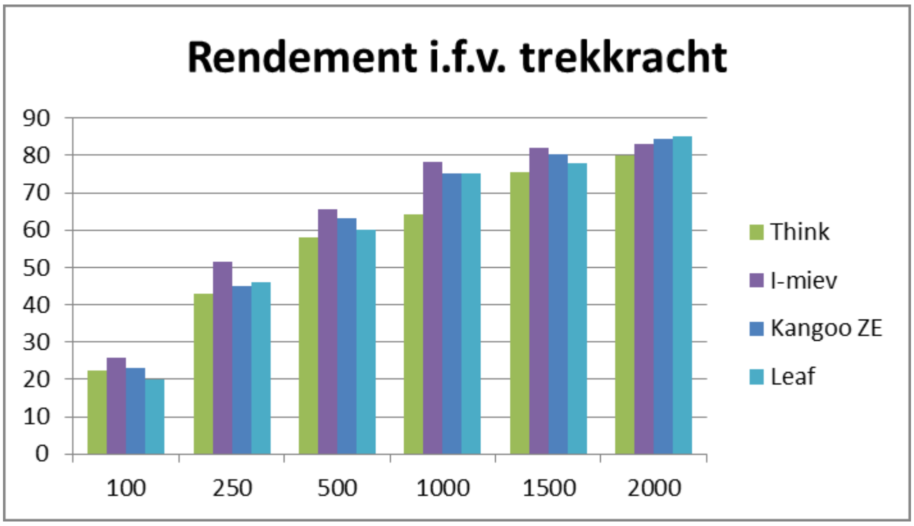

Figure 14: Comparison of yields at 50 kph

At 50 kph (Figure 14), i-Miev has the highest score, except where highest traction is concerned; in that area, Kangoo ZE and the Leaf score slightly higher. This explains why i-Miev has achieved the lowest consumption value on the NEDC cycle: best yield and extremely low vehicle weight.

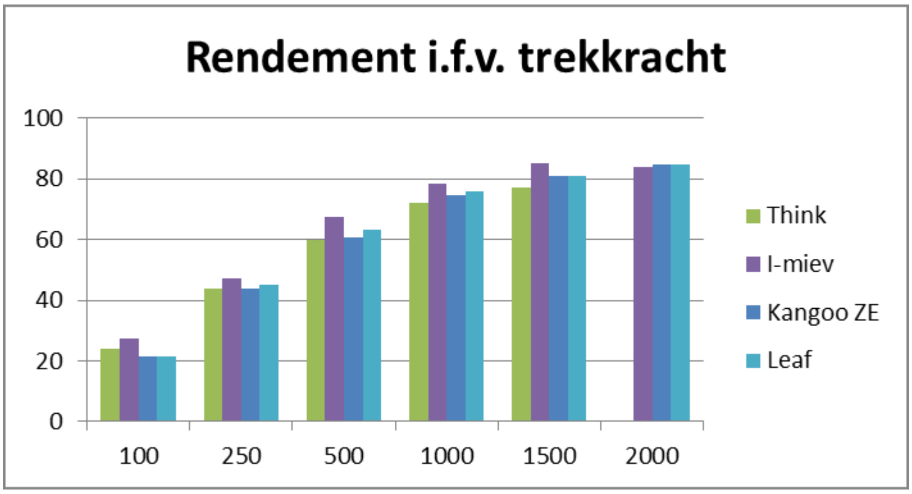

Figure 15: Comparison of yields at 70 kph

At 70 kph, the results are perfectly in line with the 50 kph ones (Figure 15).

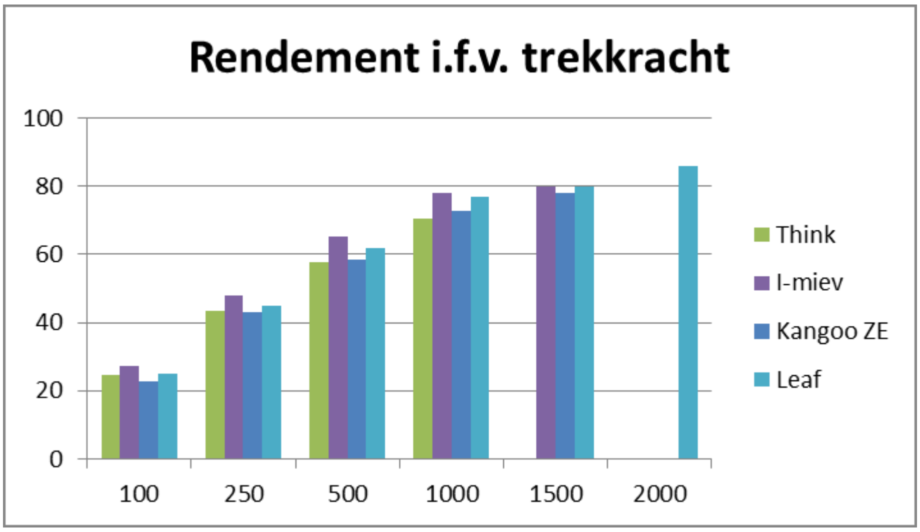

Figure 16: Comparison of yields at 90 kph

At 90 kph, the Think comes close to the transmission yield of the Kangoo ZE, the i-Miev remains the best during the three tractive powers. With a tractive power of 1500 N, the Think cannot handle the load because its maximum power is surpassed. This also happens with the i-Miev and the Kangoo ZE at a tractive power of 2000N and thus a load of 50 kW. In this area, the Leaf performs the best with an extremely high yield of 86%.

5. Charging and batteries

5.1 The vehicles' charging yield

The results of the charging yield vary considerably. However, charging yields do increase if many kWhs are required. This is the result of the various phases during the charging process. The last stage, a kind of drop charge, with limited current produces the lowest yield.

Normally a vehicle will be charged when the battery is at least 50% empty. Therefore, it can be assumed that the regular charging yield would be approximately 80% (Table 6).

	Charging yield (%)			
Load before charging	Think City	i-Miev	Kangoo ZE	Nisan Leaf II
4min. at 70kph with 500N	72	75	62	80
8min. at 70kph at 500N	80	80	69	76
Drive until entirely empty at 70kph with 250N	85	-	-	87
Drive until entirely empty at 70kph with 500N	83	84	78	88

Table 6: Charging yield

5.2 Usable vs specified battery capacity

The test, reported in Table 7, presents some differences in terms of usable and specified capacity. Main reason is the ageing of the batteries. There was practically no mileage on the Think! City tested. It was actually a new car and the battery capacity was a perfect match. The other vehicles had been driving for a year, which could explain the decreased capacity. Further study on ageing batteries would be required.

	Think City	i-Miev	Kangoo ZE	Nissan Leaf II
Usable capacity (kWh)	22,98	14,2	19,8	22,3
Specified capacity (kWh)	23	16	22	24

Table 7: Comparison usable-specified battery capacity

6. Collecting readable parameters in table format

The objective of this research is to identify the message addresses (CAN identifiers) for a number of specific messages. This includes the current and voltage of the high power battery and remaining battery capacity. In addition, parameters such as charging or not charging, distance driven, outdoor temperature, battery temperature should preferably also be registered.

All this information is transmitted on one or other of the vehicle's networks. Therefore, the first step would be to unravel and detect the network topography. This is the best way to find a junction point for these messages. Or like on the Kangoo ZE, which has two junction points, besides the CAN-Auto on the EOBD-plug there is another junction point on the CAN Electrotech (transmission).

Trying to discover these identifiers is very time consuming. In addition, it is impossible to influence the sensor current in an electric vehicle in the same way that happens for a traditional vehicle. Moreover, if information such as the traction battery's current is entered in 20 bits, it will be all the more difficult to find the correct conversion formula.

We hope that a standard will be put in place for these vehicle parameters, as is the case for cars with a combustion engine under the denominator EOBD.

7. Conclusions

Four electric vehicles has been compared, although only within the framework of reference. Ultimately, that was the overall objective.

As far as electric consumption is concerned, the numbers largely confirm the obvious understanding that a large, heavy vehicle consumes more than a small, lightweight vehicle. Which technology is used also plays a role; the PM synchronous engine transmission showed the best results.

The numbers for transmission yields also seem to state the obvious; the steady loss of the motor controllers has a negative effect if the transmission load is low. There is no way to determine the yield on an electric vehicle given the fact that it varies enormously depending on its load.

Another loss of approximately 20% occurs during charging, because of which the total yield decreases. In order to obtain the total yield, the average transmission yield must be multiplied by the charging yield.

Moreover, what about battery capacity after a few years? That will require further research.

The various vehicles all display the readable parameters differently. It will be a huge challenge to identify/calculate the correct results from the future log process.

About E-Mobility NSR

The Interreg North Sea Region project North Sea Electric Mobility Network (E-Mobility NSR) will help to create favorable conditions to promote the common development of e-mobility in the North Sea Region. Transnational support structures in the shape of a network and virtual routes are envisaged as part of the project, striving towards improving accessibility and the wider use of e-mobility in the North Sea Region countries.

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